Health Consultation

PESTICIDES IN NATIONAL PARK SERVICE BUILDINGS WITHIN
OZARK NATIONAL SCENIC RIVERWAYS NATIONAL PARK AREA

SHANNON AND CARTER COUNTIES
NEAR VAN BUREN AND EMINENCE, MISSOURI

AUGUST 22, 2014

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HEALTH CONSULTATION

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Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry (ATSDR)
Division of Community Health Investigations
Western Branch

Summary

Introduction

Agency for Toxic Substances and Disease Registry (ATSDR) prepared this health consultation in response to a request made by the U.S. National Park Service (NPS) in April 2013, to evaluate current chlordane levels in several buildings within the Ozark National Scenic Riverways (ONSR), National Park area near Van Buren and Eminence, Missouri. NPS requested the evaluation of indoor air conditions to determine if NPS buildings could currently be safely occupied for residential uses 30 years after a termiticide containing chlordane was applied in 1982 by a privately-owned pest control company contracted to perform the work.

ATSDR reviewed the investigation reports conducted since 1983. To determine current conditions, ATSDR asked the U.S. Environmental Protection Agency (EPA) to collect indoor air samples. In this report, ATSDR provides a review of the current indoor pesticide levels of several NPS buildings and evaluates the safety of their use now and for the next 30 years.

Conclusion 1

ATSDR concludes that breathing the detected levels of pesticides (technical chlordane, aldrin, DDT, and lindane) currently present in the indoor air of ONSR NPS buildings is not expected to harm people's health. Although the levels of pesticides present in indoor air have not been shown to cause adverse health effects in adults, children, or unborn children, prudent public health practice dictates reducing pesticide exposure wherever possible, especially in living spaces.

Basis for Conclusion

ATSDR evaluated the most recent sampling results collected in August-September 2013 for non-cancer and cancer health effects. Building 523B had the maximum air concentration of chlordane in the living space. When compared with published levels from the scientific literature, the levels detected in NPS buildings were well below levels that have resulted in no observed adverse effects. This indicates that people working and living within the sampled ONSR NPS buildings are unlikely to experience adverse non-cancer health effects.

ATSDR evaluated the estimated cancer risk for living space exposure durations of one, five, and 30 years. The cancer risk estimates for these periods fall within EPA's target risk range of no to slight increase in additional risk. None the less, because people are or could be exposed to pesticides, practical measures are recommended to reduce all exposures; therefore, reducing risk.

Next Steps

ATSDR recommends that NPS further reduce exposure in the treated buildings by using simple and effective measures like those NPS has successfully employed in Building 305. This is particularly important in building 523B, which had the highest indoor levels of chlordane and related compounds. This would add an additional margin of safety for occupants who use the affected buildings on a long-term basis. Measures shown to be effective when properly installed and maintained include the following:

- Installing a vapor barrier between the crawlspace and living space.
- Insuring that the HVAC does not draw from the crawlspace.
- Increasing ventilation of crawlspaces to the outside.
- Sealing entry points from the crawlspaces where pipes or wires penetrate into the living space.
- Adjusting thermostats to reduce large temperature swings by increasing the frequency that the system cycles (short cycles).
- Reducing the release of pesticides from building materials in the building interior by sealing the exposed wood, concrete, and stone surfaces (including the fireplace mantle surface).
- Limiting occupancy or consider alternative uses.

Conclusion 2

The maximum detected air concentrations of technical chlordane and aldrin were found in the crawlspaces of Buildings 445B, 473B, and 445A. While continuous long-term exposure (24 hours per day for 70 years – an unlikely situation) to the pesticides found in crawlspaces of treated buildings might result in increased risk of cancer and non-cancerous health effects, more realistic short-term crawlspace visit scenarios are not expected to harm the health of adults. Because children may be more sensitive to pesticide exposures, restricting access to treated crawlspaces is recommended.

Basis for Conclusion

Crawlspaces remain a concern in buildings treated in 1982. The air inside all three of the crawlspaces that were sampled (Buildings 305, 445, and 473) contained levels of pesticides that present a concern for continuous long-term breathing (years). The crawlspace areas of treated buildings may be the source of indoor air concentrations of pesticides. In Building 305, levels of chlordane in indoor air are acceptable while the crawlspace air is elevated. This indicates that the vapor barrier installed in Building 305 is effective in reducing indoor air concentrations. Therefore, action is needed to reduce exposure to crawlspace air in other buildings that were treated.

Next Steps

ATSDR recommends that NPS take steps to reduce exposure to crawlspace air in all buildings that were treated. Measures shown to be effective include the following:

- Preventing children from accessing the crawlspaces.
- Limiting the time adults spend in the crawlspace.
- Changing clothes and washing hands immediately after accessing the crawlspace.
- Washing contaminated clothes separately from other household laundry.
- Placing stored items in vapor proof material or not storing items in the crawlspace.

Conclusion 3

Information provided to ATSDR indicates that chlordane may have been applied directly onto interior surfaces of some ONSR NPS buildings. In addition, some living space air samples were found to contain trace levels of aldrin and DDT. While the levels are too low to present a health hazard for breathing, it is unusual to find these chemical in the air and may indicate that those pesticides were also applied directly onto interior surfaces. Wipe-sampling of interior surfaces is needed to determine whether contaminated interior surfaces may represent a health concern to young children.

Basis for Conclusion

In addition to chlordane, the pesticides aldrin and DDT were also found in the air of some buildings, suggesting that surfaces were sprayed and continue to release pesticides into the indoor air. Although the levels of DDT were low, it is extremely rare to find DDT levels in air because DDT binds so tightly to organic material such as soil and wood and does not readily volatilize into air.

During sampling, some buildings were cleaned by the housekeeper. Interior surfaces may have been wetted causing DDT to be released into the air. Children are at a greater risk than adults because they spend more time near the areas that were likely sprayed with pesticides, such as floor boards. Children often have continuous hand-to-mouth activity likely resulting in greater contact and ingestion of pesticide residues.

Next Steps

ATSDR recommends that NPS consider taking surface wipe samples to determine if surfaces present a hazard to small children and painting or sealing the wood that was treated with aldrin or DDT in the past. ATSDR is available to review and comment on recommended sampling results when they have been obtained.

Site Description and History

The Ozark National Scenic Riverways (ONSR), National Park was established in 1964 as the first national park area to protect a wild river system [NPS 2013]. Prior to the ONSR becoming a national park, it was Missouri State public land. ONSR includes many areas along two river systems: Jacks Fork River and Current River. ONSR stretches across 80,000 acres in Shannon, Carter, Dent, and Texas counties near the towns of Van Buren and Eminence in southern Missouri. ONSR areas are managed by the National Park Service (NPS). Adjacent to areas of the ONSR are Ozark National Forest managed by the U.S. Forest Service and state owned "Missouri Natural Areas" managed by the Missouri Department of Conservation [Price No Date].

The ONSR area includes the cold spring-fed Jacks Fork River and the Current River, hundreds of freshwater springs, caves, trails, and historic sites. Within the ONSR, the NPS maintains over 100 buildings including NPS employee offices and residences, rental cabins, visitors centers, dining facilities, and picnic shelters [NPS 2013]. Occupancy ranges from a few weeks in rental cabins to 20 years for employee residences.

Pesticide Application

In October 1982, following a termite inspection of NPS-owned structures, 58 buildings in the areas of Big Spring, Alley Spring, Powder Mill, and Round Spring were treated for termites with a pesticide containing chlordane. In February 1983, during a renovation project, one of the ranger's quarters, Building 305, was found to still be infested with termites. NPS contacted the contract pest control firm to re-treat the building. Although the standard building treatment was to inject the pesticide into the soil surrounding structures, NPS employees reported that in some buildings a pesticide containing chlordane was topically applied to the interior wallboard, fireplace, interior framing, floor joists and sills, and holes were drilled in the concrete floor slab to inject the pesticide [NIOSH 1997]. The residents of Building 305 reported strong and persistent odors. NPS contacted the National Institute for Occupational Safety and Health (NIOSH) for assistance in addressing the concerns with the pesticide application [NIOSH 1997].

Previous Investigations

NIOSH sampled for chlordane in multiple NPS buildings and conducted several Hazard Evaluations and Technical Assistance reports (HETAs) dated 1983, 1987, 1990, 1996, and 1997 [NIOSH 1983, 1984, 1987, 1990, 1996, 1997]. Appendix A details the timeline and actions taken during the previous investigations. Buildings included in the pesticide evaluations range in construction material and age – built from the 1930s to the 1960s – and have varied features. Appendix B contains details of the buildings.

Additionally, NIOSH conducted medical evaluations of the occupants of several buildings. Serum was tested for chlordane and its metabolites. NIOSH found no uniform pattern of symptoms or reported medical conditions [NIOSH 1983, 1987]. NIOSH determined that buildings containing less than 5 $\mu g/m^3$ of chlordane could be occupied for residential use. On the advice of NIOSH, buildings with indoor air chlordane concentrations greater than 5 micrograms per cubic meter [$\mu g/m^3$]); were taken out of use [NIOSH 1983, 1984, 1987, 1990, 1996, 1997].

In 2012, NPS contracted with ToxFree, Inc., a private consulting firm, to evaluate pesticides in the indoor air of Buildings 248A&B, 473A&B, 523A&B, and 305. ToxFree concluded that concentrations of technical chlordane were above cancer and non-cancer risk levels. They presented the results of their air sampling and risk calculations in two letters dated November 26, 2012, and January 20, 2013, each with accompanying spreadsheets depicting the evaluation methodology [ToxFree 2012, 2013].

> Technical chlordane refers to the grade and purity of the chlordane product (solution or powder). There are as many as 15 chemical grades of purity available based on the intended use and cost. Technical chlordane is 80 to 90% pure. Technical grade is the least pure and suitable for most industrial applications including use as a pesticide. Increasing purity grades include “Laboratory-Grade”, “Pharmaceutical-Grade”, and “ACS-Grade” certified by the American Chemical Society as the highest purity.

NPS shared the ToxFree letters with NIOSH, requesting their response. In the June 2013 letter from NIOSH to NPS, NIOSH describes some details of the ToxFree sampling methods. NIOSH concluded that the approaches used in the NIOSH investigations and those used by ToxFree were not comparable primarily because the consultant performed a risk assessment on exposure to technical chlordane and NIOSH measured occupational exposure to chlordane [NIOSH 2013].

In April 2013, NPS contacted ATSDR to request a health consultation. ATSDR requested that EPA collect air samples at selected NPS-prioritized buildings to serve as the basis for the health consultation [Tetra Tech 2013a, 2013b, 2013c]. This health consultation focuses on the most recent data collected by EPA/Tetra Tech, Inc. [Tetra Tech 2013b, 2013d, 2013e].

Methods and Results

Sampling

Between August 6-8, 2013, EPA and its contractors collected 22 indoor air samples from six buildings (including three duplexes represented by the designation A&B) for analysis of organochlorine pesticides. Each 24-hour sample was collected in accordance with EPA Method TO-10A. The air sample inlets were set at a breathing zone height of approximately 5 feet above the floor.

The selected buildings were considered by NPS to be their highest priority based on previous history of pesticide treatment; past, current, and potential future occupancy; and results of previous sampling events [Tetra Tech 2013a]. Constituents of chlordane were detected in those samples. NPS requested follow-up sampling of additional buildings for analysis of organochlorine pesticides [Tetra Tech 2013b]. Between September 10-12, 2013, an additional 23 samples were collected at 18 other buildings (including one duplex) [Tetra Tech 2013d]. In total, during the two sampling events, 45 air samples were collected from 24 buildings (including four duplexes). The samples were taken within indoor living, working, and exercise areas, and the crawlspaces of three buildings (one duplex) [Tetra Tech 2013e].

Sampling Results

Substances Detected in Indoor Air

Summary results of the August/September 2013 indoor air sampling show that 10 organochlorine pesticide-related substances were detected. Table 1 summarizes the data and Appendix E shows the full data. The predominate compounds detected in the NPS buildings were alpha α (cis-) chlordane

and gamma γ (trans-) chlordane isomers, heptachlor, and heptachlor epoxide. The data support the idea that the pesticide applied in these buildings was primarily technical chlordane because the three most frequently detected chemicals are the major components of technical chlordane. Technical chlordane consists of four major compounds: cis-chlordane, trans-chlordane, heptachlor, and trans-nonachlor [Cassidy 1994]. Alpha α (cis-) chlordane, gamma γ (trans-) chlordane, heptachlor, heptachlor epoxide, and aldrin were detected. However, trans-nonachlor was not detected.

Heptachlor epoxide is the major metabolite of heptachlor and shows up as the fourth most frequently detected substance in NPS buildings. Aldrin is not a documented component of technical chlordane, but is a separate pesticide. Detection limits for all analytes in the air samples ranged from 0.0069 to 0.0078 $\mu g/m^3$. In general, higher levels of organochlorine pesticides were found in samples collected from crawlspaces than in samples from indoor living/working/exercising areas.

The most common analytes detected in the samples were gamma-chlordane (in 43 samples, at up to 1.3 $\mu g/m^3$); alpha-chlordane (in 41 samples, at up to 0.77 $\mu g/m^3$); heptachlor (in 36 samples, at up to 0.61 $\mu g/m^3$); and heptachlor epoxide (in 34 samples, at up to 0.20 $\mu g/m^3$). All are constituents (or constituent metabolites) of technical chlordane.

Other detected organochlorine pesticide-related compounds included endrin, 4,4'-dichlorodiphenyltrichloroethane (DDT), 4,4'-dichlorodiphenyldichloroethene (DDE), gamma-hexachlorocyclohexane (BHC), and delta-BHC. All of these compounds were detected in a small number of buildings.

Table 1. Summary Results of Aug-Sept 2013 Indoor Air Sampling Event

Chemical Substance	Detects	Concentration Range ($\mu g/m^3$)*	
		Minimum	Maximum
γ-Chlordane (gamma)	42/45	0.0086	1.3000
α-Chlordane (alpha)	40/45	0.0090	0.7700
Heptachlor	35/45	0.0070	0.6100
Heptachlor Epoxide	33/45	0.0071	0.2000
Aldrin	6/45	0.0075	0.0340
4,4'-DDT	6/45	0.0075	0.0140
γ-BHC (gamma) lindane	5/45	0.0075	0.0180
Endrin	2/45	0.0093	0.0200
δ -BHC (delta)	1/45	0.0100	0.0100
4,4'-DDE	1/45	0.0089	0.0089

* Exposure Concentration in $\mu g/m^3$ (micrograms per cubic meter).

ATSDR uses a series of steps to quantitatively assess the need for more in-depth evaluation by comparing detected concentrations with various environmental and health screening criteria or comparison values. Detected concentrations which are greater than screening criteria do not mean that a hazard exists, only that ATSDR needs to take additional steps to evaluate the potential hazards.

Discussion

The most frequently detected pesticides at ONSR NPS building are those present in technical chlordane. Concentrations of pesticides have been slowly but steadily decreasing in the NPS buildings since 1983. Despite the widespread use of these organochlorine pesticides to treat homes in the southern U.S., where millions of people were exposed, toxicological studies of the health effects of chronic low dose exposures are not available. Thirty-four years after NPS buildings were treated, there exist few additional toxicological studies on which to base an evaluation. Possible reasons for the lack of scientific information could be that the effects of chlordane exposures are common to other diseases or conditions and are masked or not thought to be related to chlordane exposure. Another possible reason for the lack of adverse effect evidence may be that despite widespread use and exposure, the amount of the substances taken in by the body does not demonstrate an apparent effect on the body at low doses. However, high dose exposures have been shown to produce numerous effects that are not apparent at low doses, but are used as the basis (benchmark) for adverse health effects.

ATSDR uses risk assessment methodology as one tool in our public health assessment process. Risk assessment does not result in a final answer because it is impossible to determine the true magnitude and extent of any exposure to actual site contamination. Research on the effects of chemicals on animals and humans is patchy and incomplete, confounded by many factors such as: variations in individual and species tolerances to the effects of contaminants; environmental conditions and processes affecting the properties of the contaminant such as partitioning, transformation, degradation, temperature, pH, organic material, etc; uncertainty in extrapolating study data between species (e.g. using the outcome of animal testing to predict the effect on people) and within species (e.g. using the effects on a specific group of workers such as miners to predict the effect on other groups of people such as children); large information gaps about the effects of contaminant mixtures that might have synergistic, magnifying or other effects; and large information gaps about the specific mechanisms and processes affecting functions and organs within the body, how these interact, and how they might be affected by a contaminant [LCR 2007].

Understanding of the interactions between affected individual people and animals within a population, populations within a community, and communities within habitats and ecosystems is extremely limited.

What is known:

- More than 52 million people throughout the United States have been exposed to technical chlordane used to treat homes for more than 40 years [ATSDR 1993a].
- Indoor air living space of treated homes throughout the U.S. were reported in 1994 to contain average levels of chlordane between 0.03 and 2.0 $\mu g/m^3$ with the highest level being 60 $\mu g/m^3$. Even higher levels are found in basements and crawl spaces of these homes (ATSDR 1994).

- In general, exposure levels around the US are much lower today than 30 years ago.
- Studies of health effects associated with exposure to the concentrations of technical chlordane commonly present in residences are few, incomplete, and do not provide sufficient evidence for certainty.
- More evidence is available for health effects at higher concentrations, usually from reports of pesticide applicators or accidents involving exposure to the concentrated solution prior to it being diluted and applied (or misapplied).

Chlordane and Technical Chlordane

The term chlordane typically refers to the substance that is actually technical-grade chlordane or "technical chlordane" which contains about 10% to 20% other compounds. Technical chlordane is a less pure substance that is made up of a complex mixture of the chlordane isomers, other chlorinated hydrocarbons, and more than 140 related reaction products. Most of these compounds are minor or trace components [ATSDR 1994].

Sixty to 85% of technical chlordane consists of the stereoisomers cis-and trans-chlordane [Buchert 1989]. Cis-chlordane is also known as (alpha-) α-chlordane. Trans-chlordane is commonly known as (gamma-) γ-chlordane, although it is occasionally referred to as (beta-) ß-chlordane [EPA 1984; CAS 1992]. The different isomers are named according to the position of the hydrogen atoms in the structure of the chemical. In most temperate climates, only the two chlordane isomers: alpha and gamma chlordane, generally persist in the environment [WHO 1984]. The ratio of the alpha and gamma isomers and amounts of other compounds (impurities) depends on the manufacturing process [Buchert 1989].

Although pure chlordane isomers can be produced and purified, it is the more impure technical-grade chlordane that has been widely used as a pesticide and also used in toxicological studies from which come the standards for occupational and non-occupational exposures [OSHA 2013].

Chlordane was used widely as an insecticide on food crops and as a termiticide in buildings and homes. It was sold as both a white dusting powder and as a liquid concentrate. It is semi-volatile, volatilizing in hot environments, but not under cooler conditions. Chlordane is insoluble in water and was diluted in hydrocarbon solvents and sprayed as a 0.5 to 2.0% emulsion for termite control, and as a 3.0 to 4.25% solution for above ground structural wood treatment. Application typically involved trenching, subslab injection, low pressure spray for subsurface termite control and brush, spray, or dip for applying to structural wood [DOA 1958; WHO 1978].

Since 1988, the use and commercial production of chlordane has been prohibited in the United States and many other countries. However, chlordane residue is still present from prior use in many homes and other structures, as well as in the surrounding soil because chlordane is very persistent in the environment. U.S. production of chlordane was suspended in 1976, in response to data from human monitoring studies showing that 90 percent of all Americans had residues of chlordane metabolites in their tissue and that these metabolites may be transferred from mother to the fetus across the placenta and from mother to child via mother's milk. The principal cis- and trans-isomers of chlordane and the component heptachlor may be metabolized to epoxides, oxychlordane and heptachlor epoxide, both

of which have been detected in human tissues [Nomeir and Hajjar, 1987]. In 1997, the world's last producer of chlordane, the U.S.-based Velsicol Chemical Corporation, announced that it would permanently cease production. Roughly 30 million houses have been treated with technical chlordane or technical chlordane mixed with heptachlor [Liddle 1988].

Heptachlor and Heptachlor Epoxide

Heptachlor was used extensively in the past for killing insects in homes, buildings, and on food crops, especially corn. These uses were stopped in 1988. Technical-grade heptachlor was also used as a pesticide, and was a constituent of technical chlordane. Technical heptachlor is less expensive than pure heptachlor and contains about 72% heptachlor and about 28% related compounds such as trans-chlordane (20-22%) and trans-nonachlor (4-8%) [ATSDR 2007].

Currently, it can only be used for fire ant control in power transformers. Bacteria and animals break down heptachlor to form heptachlor epoxide. About 20% of heptachlor is changed within hours into heptachlor epoxide in the environment and in the body. The epoxide form is more likely to be found in the environment than heptachlor [ATSDR 2005]. Heptachlor is relatively insoluble and noncombustible, but may be dissolved in flammable liquids [ACGIH 2001; ATSDR 2007].

Public Health Implications

Several pesticides were found in the living space air samples of ONSR NPS buildings at moderately low levels. These chemicals were applied more than 30 years ago, yet traces are still present. The risks for each of these chemicals are presented below. Each, individually present a low risk. The combined risk cannot be adequately addressed by using conventional additive methods. Although combined risks for some effects have been studied for aldrin, heptachlor, and chlordane, combined risks of exposure are not fully understood [ATSDR 1994, ATSDR 2013].

Chlordane

ATSDR combined the detected concentrations of alpha chlordane, gamma chlordane, and heptachlor for each sample to give a representative technical chlordane concentration which is used in our evaluation, and compared directly to EPA’s Reference Concentration for non-cancer health effects (Appendix D – Methods).

Studies of experimental animals exposed to acute high levels of chlordane, >40,000 times higher than levels found in NPS buildings, have shown effects of the nervous system, the digestive system, and the liver. Sufficient chlordane exposure by any route disrupts the transmission of nerve impulses, resulting in CNS excitation, convulsions, and respiratory depression. Headaches, irritability, confusion, weakness, vision problems, vomiting, stomach cramps, diarrhea, and jaundice have occurred in people who breathed air containing high concentrations of chlordane or accidentally swallowed chlordane [ATSDR 1995]. The exposures at ONSR are not at these high levels. The World Health Organization classified technical chlordane as moderately hazardous. Most of its metabolites are slightly to moderately toxic [WHO 1984].

Comparison values for non-cancerous effects are based on a 90-day inhalation study in male and female rats exposed to technical chlordane at 0, 100, 1,000, or 10,000 $\mu g/m^3$ for 8 hours/day, 5 days/week, for 13 weeks, followed by a 13-week recovery period. Reported health effects include

mild liver lesions (hepatocellular enlargement or vacuolization) and slight changes in serum chemistry at ≤1,000 μg/m^3 and increased liver weight in both sexes at 10,000 μg/m^3 [Khasawinah 1989; Velsicol 1984]. The lowest concentration, 100 μg/m^3, was the No Observed Adverse Effect Level (NOAEL) because no effects were seen. Therefore, 100 μg/m^3 serves as the basis for ATSDR's MRLs as follows: 1) an intermediate-duration MRL of 0.2 μg/m^3; the study concentration was adjusted to account for longer duration from intermittent exposure (8/24 hours times 5/7 days = 0.2) and divided by an uncertainty factor of 100 (10 to extrapolate from animals to humans and 10 for human variability) and 2) a chronic-duration inhalation MRL of 0.02 μg/m^3, the study concentration was adjusted for intermittent exposure (0.2) and divided by an uncertainty factor of 1,000 (10 to extrapolate from animals to humans, 10 to extrapolate from an intermediate duration to a chronic duration, and 10 for human variability).

EPA's Reference Concentration (RfC) 0.7 μg/m^3 is also based on the above study. Using dosimetric modeling and Regional Deposited Dose Ratio (RDDR) for extra respiratory particles, EPA calculated a health effect concentration of 650 μg/m^3 and divided by an uncertainty factor of 1,000 to extrapolate from animals to humans, 10 to extrapolate from an intermediate duration to a chronic duration, and 10 for human variability [EPA 2009][1]. EPA's RfC represents a more recent review of the data and therefore serves as the basis for our non-cancer comparison value.

Chlordane, heptachlor, and heptachlor epoxide have been classified by the International Agency for Research on Cancer (IARC) as possibly carcinogenic to humans based on findings of increased incidences of liver tumors in mice fed these substances for a lifetime [IARC 2001].

EPA has determined that technical-grade chlordane and heptachlor are likely human carcinogens. EPA has derived Inhalation Unit Risk (IUR) values for these pesticides from linear multi-stage extrapolations. No studies were located regarding carcinogenic effects in animals after inhalation exposure to chlordane. EPA derived a unit risk in air from doses derived from a dietary study of chlordane fed to rats that developed liver cancer [EPA 1992].

In 1979, the National Research Council's (NRC) Committee on Toxicology developed an interim chlordane standard of 5 μg/m^3 at the request of the Department of Defense to assist in determining the safety of chlordane-treated military family housing [NIOSH 1987]. NRC reported that they could not determine a level of exposure to chlordane below which there would be no biological effect for long-term exposure of families in military housing. Using a variety of pragmatic factors, NRC issued an interim value. The primary factor was to reduce risk in the top 2% of homes in this specific situation. The interim value was not intended to be the reference value for more than 30 years [NIOSH 1984].

In animal studies, the critical effect of hepatic toxicity was consistent across routes of exposure because oral studies also indicate hepatotoxicity as the critical endpoint of toxicity [Khasawinah 1989]. However, there is some indication that neurotoxicity, a known human endpoint in acute exposures, may be a relevant endpoint in chronic human exposures. Few chronic animal studies have examined neurotoxicity [ATSDR 2013].

1 Using dosimetric modeling and Regional Deposited Dose Ratio (RDDR) for extra respiratory particles, EPA calculated an effect level (at 650 μg/m^3) between the measured effect level of 1000 μg/m^3 and NOAEL of 100 μg/m^3. Then they added uncertainty factors: 650 μg/m^3 ÷ 1000 = 0.65 μg/m^3 and rounded to 0.7 μg/m^3.

Public Health Implications for Reproductive Health and Pregnancy Outcomes from Chlordane
ATSDR reviewed the scientific literature to determine if technical chlordane has been implicated in adverse pregnancy outcomes such as sterility or still births. It is not known whether chlordane will cause reproductive or birth defects in humans. The body of evidence regarding chlordane exposure at levels found in indoor air suggests that exposure to *chlordane has not been shown to result in adverse pregnancy or reproductive outcomes* [ATSDR 1994 and 2013].

No studies were found that showed adverse pregnancy outcomes from inhalation of technical chlordane. Additionally, no studies or case reports of adverse pregnancy outcomes were found for pesticide exposure to indoor air concentrations.

The Extension Toxicology Network, a pesticide information project of Cooperative Extension Offices of Cornell University, Oregon State University, the University of Idaho, the University of California at Davis, Michigan State University, and the Institute for Environmental Toxicology, has a database last updated in June 1996 that states the following:

> ***"Reproductive effects:*** *Chlordane has been shown to affect reproduction in test animals. Fertility was reduced by about 50% in mice injected with chlordane at 22 mg/kg once a week for 3 weeks. The data suggest that reproductive effects in humans are unlikely at expected exposure levels.*
>
> ***Teratogenic effects:*** *No teratogenic effects were observed in rats born to dams fed chlordane at 5 to 300 mg/kg/day for 2 years [20]. It is unlikely that chlordane will cause teratogenic effects in humans.*
>
> ***Mutagenic effects:*** *Chlorinated hydrocarbon insecticides (such as chlordane) are generally not mutagenic. It was reported that 15 out of 17 mutagenicity tests performed with chlordane have shown no mutagenic effects. Thus, chlordane is weakly or nonmutagenic."*

The University of Washington, Department of Pediatrics compiles several databases on reproductive toxicology including the Teratogen Information System (TERIS) database. The TERIS database states that no epidemiologic studies have reported birth defects among infants born to mothers exposed to chlordane or heptachlor during pregnancy. Neither chlordane nor heptachlor are included in Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. No teratogenic effects, (including hydrocephalus), from acute exposure have been reported.

ATSDR found one rat study from Ambrose in 1953 that showed decreased fertility and survivability in animals given an oral dose of 16 mg/kg/day (~10,000 greater than the equivalent dose for people exposed in NPS buildings) [ATSDR 2000].

A cross-sectional epidemiological investigation involving women exposed to chlordane vapors did not provide conclusive evidence that the reproductive system is a potential target organ in humans exposed to chlordane [Menconi 1988].

Histopathological (tissue damage) effects on the reproductive organs were not observed in rats exposed to chlordane in air at 28.2 mg/m^3 (40,000 times greater than the indoor air levels in NPS buildings) 8 hours/day, 5 days/week for 28 days, or in rats or monkeys similarly exposed to 10 mg/m^3 for 90 days (14,000 times greater than the indoor air levels in NPS buildings) [Khasawinah 1989].

In a reproductive study of two generations of rats exposed orally to technical chlordane at four dose levels 100 to 1,000 times greater than equivalent doses for people exposed in NPS buildings showed sperm cells motility, velocity, morphology and concentration as well as plasma testosterone levels to be unaffected. Researchers found no effect on fertility, pregnancy outcome, indices of puberty, total litter weight, litter size, or sex ratio of both generations. Increased uterine weight was found in F0 dams (grandmothers) at the lowest dose, but not at the higher doses. In the F2 males (grandsons) they found reduced testicular weight at the second lowest dose level, but not at any other dose levels [Mansour 2002]. Additionally, combined exposure to chlordane and lead oxide was found to have greater impact on testicular tissues in male mice [Al-Omar 2000].

A mixture of technical chlordane, polychlorinated biphenyls (PCBs), and 13 other chemicals were given to sows and also given to *in vitro* embryos at levels 1,000 to 10,000 times greater than the levels detected in NPS buildings. The metabolized mixture was extracted from the sows and given *in vitro* to embryos. The study concluded that high concentrations of the organochlorine mixture were toxic to porcine embryos in a dose dependent manner. They further concluded that concentrations of either the native or the metabolized mixture that bear some relevance to exposure of human populations were without observable effect [Campagna 2008].

Exposure to chlordane in indoor air has not been shown to result in adverse pregnancy or reproductive outcomes.

NPS-Specific Evaluation of Chlordane

The constituents of technical chlordane were detected in the indoor air of 22 of the 24 buildings sampled. The measured concentrations are plotted in Figure 1. The maximum detected values 2.137, 1.58, and 1.32 $\mu g/m^3$ were found in the crawlspaces of Buildings 445B, 473B, and 445A.

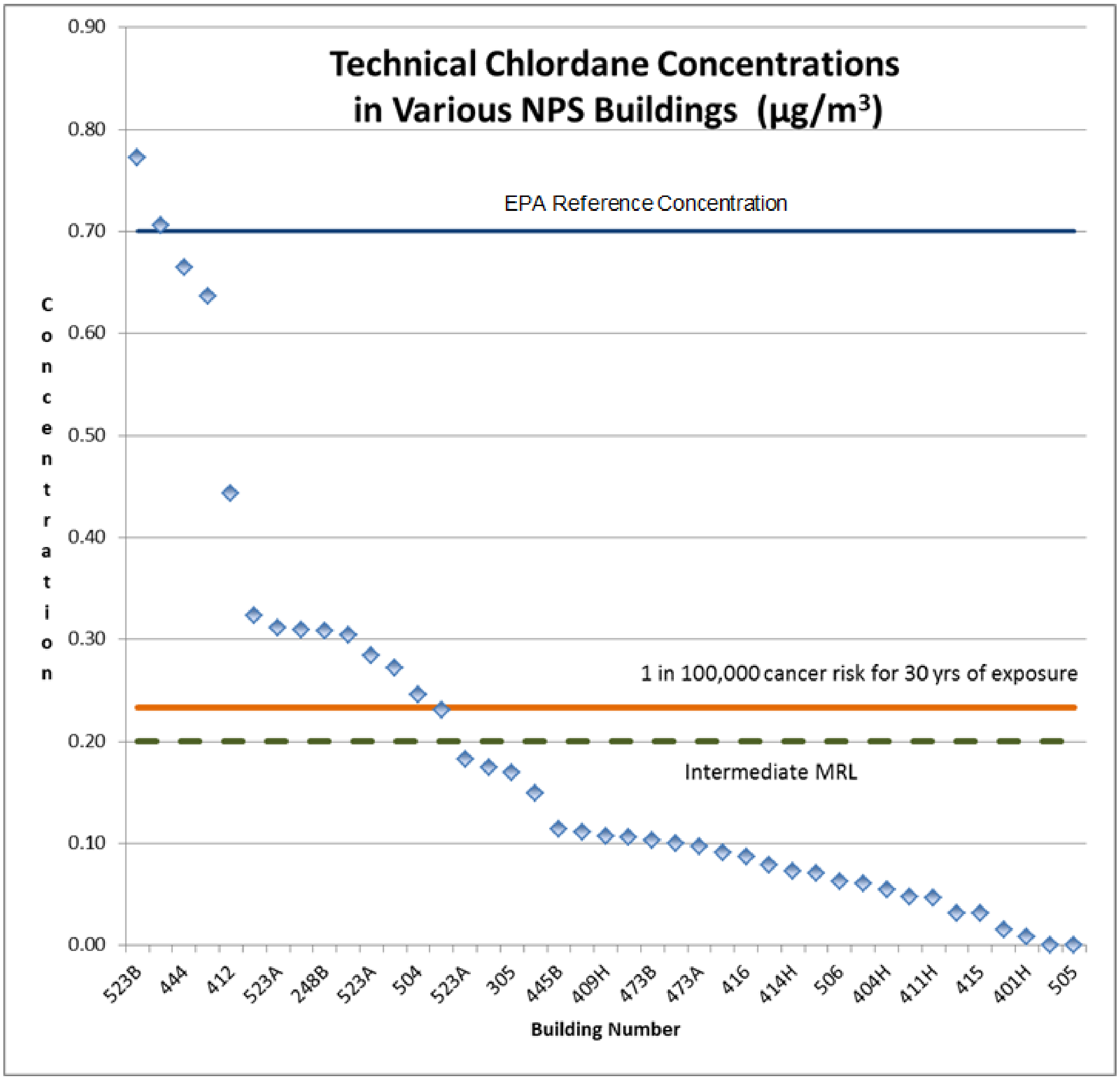
The maximum detected values in indoor air were found in one side of the duplex of Building 523. The 523A side of the building is used as office, meeting, and exercise space. The 523B side of the building is used as residential space. Building 523B had a maximum air concentration of chlordane in the living space of 0.772 $\mu g/m^3$ which is slightly higher than EPA's RfC of 0.7 $\mu g/m^3$, but well below the No Observed Adverse Effect level of 100 $\mu g/m^3$. EPA's RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure. **This indicates that people working and living within the sampled ONSR NPS buildings are unlikely to experience adverse non-cancer health effects.**

ATSDR evaluated the cancer implications for exposure durations for one, five, and 30 years. Table 2 depicts the affect the number of years someone resides in a building has on the estimated cancer risk.

EPA has derived a carcinogenic IUR of $(1.0 \times 10^{-4})^{-1}$ µg/m^3 for a 70 year exposure. ATSDR modified this value (multiplied by 30/70) for a 30 year exposure and similarly for 5- and 1- year exposures that would be more common for visitors and workers who reside at the park during their employment. Multiplying the 30 year IUR by the maximum indoor air exposure concentration (0.772 µg/m^3) gives a cancer risk value of 3.3×10^{-5} for a 30-year exposure, 5.5×10^{-6} for a 5-year exposure 1.1×10^{-6} for a 1-year exposure for Building 523B. The 1 in a 100,000 (1×10^{-5}) cancer risk level associated with 30 years of continuous exposure is plotted in Figure 1. The cancer risk estimates for these periods fall within EPA's target risk range for Superfund of 1.0×10^{-6} to 1.0×10^{-4} (1 in 1,000,000 to 1 in 10,000) which indicates no to slight increased additional risk for Building 523B. Lower levels were found in the working space side of the duplex at the 10^{-6} risk. Building 444 also has a slight increase in cancer risk in the range of 2.7 to 2.8×10^{-5}.

Because there are few human inhalation studies of technical chlordane, there is a great deal of uncertainty in the validity of applying numerical calculations to health or risk assessments. For that reason, risk characterization for NPS buildings is limited and cannot be used to predict health outcomes. Instead, ATSDR emphasizes that measures focus on preventing, reducing, or eliminating the risk. Prudent public health practice dictates reducing pesticide exposure wherever possible, especially in living spaces. Measures to reduce indoor air levels of contaminants in buildings or to reduce human contact will reduce health risk. The crawlspace areas of treated buildings appear to be the source of indoor air pesticides. In Building 305, levels of chlordane in living space indoor air are low, while the crawlspace air is elevated well above that in the living space. This indicates that the vapor barrier installed in Building 305 is effective in reducing indoor air concentrations.

Figure 1: Technical Chlordane Indoor Air Concentrations and Estimated Risk Values.



EPA Reference Concentration – 0.70 µg/m³
30-year Cancer Risk Ranges Target for 10^{-4} to 10^{-6} = 2.35 to 0.0235 µg/m³ Technical Chlordane
5-year Cancer Risk Ranges Target for 10^{-4} to 10^{-6} = 14 to 0.14 µg/m³ Technical Chlordane
1-year Cancer Risk Ranges Target for 10^{-4} to 10^{-6} = 70 to 0.70 µg/m³ Technical Chlordane

Table 2. Technical Chlordane* Cancer Risk Estimates For Continuous Exposure Durations (24hr/7days) of 1, 5, and 30 Years

Building ID	Room	Tech Chlordane µg/m^3	Cancer Risk using IUR for 30 years	Cancer Risk using IUR for 5 years	Cancer Risk using IUR for 1 year
523B	LS	**0.772^**	3.31E-05	5.51E-06	1.10E-06
523B	BR	**0.706^**	3.03E-05	5.04E-06	1.01E-06
444	LS	0.665	2.85E-05	4.75E-06	9.50E-07
444	BR	0.637	2.73E-05	4.55E-06	9.10E-07
412H	LS	0.443	1.90E-05	3.16E-06	6.33E-07
248B	BR	0.323	1.38E-05	2.31E-06	4.61E-07
523A	MS	0.311	1.33E-05	2.22E-06	4.44E-07
248A	BR	0.309	1.32E-05	2.21E-06	4.41E-07
248B	LS	0.308	1.32E-05	2.20E-06	4.40E-07
248A	LS	0.304	1.30E-05	2.17E-06	4.34E-07
523A	O	0.284	1.22E-05	2.03E-06	4.06E-07
445A	LS	0.272	1.17E-05	1.94E-06	3.89E-07
504	LS	0.246	1.05E-05	1.76E-06	3.51E-07
504	BR	0.231	9.90E-06	1.65E-06	3.30E-07
523A	WM	0.182	7.80E-06	1.30E-06	2.60E-07

LS = Living Space, BR = Bedroom, MS = Meeting Space, O= Office , WM = Weight (Exercise Room)
*Technical chlordane is represented by the additive total of constituents γ-Chlordane (gamma), α-Chlordane (alpha), and Heptachlor. ^Exceeds EPA RfC of 0.7 µg/m^3.

Aldrin

Aldrin is a persistent organochlorine pesticide that was used for corn and cotton crops and for treatment of timber against termite infestation from the early 1950s until 1987 when the manufacturer voluntarily cancelled the registration for its use. It does not dissolve in water, but readily dissolves in solvents such as toluene and petroleum distillates. It binds tightly to the organic matter in soil and wood. However, it does volatilize slowly into the air [ATSDR 2002].

Once aldrin is taken into the body, it almost immediately changes to dieldrin. Dieldrin was also manufactured and used as a pesticide. Data regarding the health effects of aldrin in humans come from either epidemiological reports of occupational exposure or case reports of accidental or intentional poisonings. However, exposure levels or the amount of aldrin taken into the body in these studies or case reports are not available. Therefore, these studies are inadequate for quantitative assessment of the health effects of aldrin or dieldrin [ATSDR 2002].

In humans, exposure to high, but unmeasured levels of aldrin or dieldrin has been associated with central nervous system excitation culminating in convulsions. However, ATSDR does not anticipate that ONSR-related exposures would be this high. Longer-term exposure of humans in occupational settings has also been associated with central nervous system intoxication, headaches, dizziness, hyperirritability, general malaise, nausea and vomiting, anorexia, muscle twitching, and muscle jerking [Jager 1970; Kazantzis 1964]. The liver was the most sensitive target of aldrin and dieldrin toxicity in chronic-duration animal studies [ATSDR 2002]. Studies examining the inhalation toxicity

of aldrin in humans are limited. Therefore, ATSDR could not develop an inhalation MRL due to insufficient data [ATSDR 2002].

The International Agency for Research on Cancer has categorized aldrin and dieldrin as Group 3 (unclassifiable as to human carcinogenic potential) chemicals. Based on the finding of liver tumors in mice, EPA classified both aldrin and dieldrin as B2, probable human carcinogens; however, current mechanistic data suggest that the mouse carcinogenicity data may not be highly relevant to humans [ATSDR 2002].

NPS-Specific Evaluation of Aldrin

Aldrin was detected in six of 45 samples (see Table 3). The maximum detected values 0.034 and 0.019 µg/m^3 were found in the crawlspaces of Buildings 445 and 473. Building 444 had aldrin at0.019 µg/m^3 in living space air. Due to insufficient scientific information, ATSDR has not established a non-cancer inhalation comparison value for this chemical. However, based upon the toxicological studies, the potential exposures in NPS buildings are much lower than those expected to result in non-cancer health effects. Nevertheless, since these chemicals are found to be present along with other pesticides, they warrant further evaluation.

EPA has derived an IUR of $(4.9 \times 10^{-3})^{-1}$ µg/m^3 for a 70 year lifetime continuous exposure. ATSDR modified this value (multiplied by 30/70) for a 30 year exposure. Multiplying the 30 year IUR by the maximum indoor air exposure concentration (0.019 µg/m^3) gives a cancer risk value of 3.9×10^{-5}. ATSDR compared the estimated increased cancer risk with EPA's target risk range for Superfund of 1.0×10^{-6} to 1.0×10^{-4} (1 in 1,000,000 to 1 in 10,000) which indicates a slight increase in cancer risk for Buildings 444 and 504.

Because too few human inhalation studies appear in the scientific literature, there is a great deal of uncertainty in the validity of applying numerical calculations to health or risk assessments. For that reason, risk characterization for NPS buildings is limited and cannot be used to predict health outcomes. Instead, ATSDR emphasizes that measures are needed to prevent, reduce, or eliminate the risk.

Table 3. Estimated Cancer Risk from Levels of Aldrin in NPS Buildings			
Building	Room§	Aldrin Concentration ($\mu g/m^3$)*	Estimated Cancer Risk† Using EPA's Inhalation Unit Risk of $(4.9 \times 10^{-3})^{-1}$
445B	CS	0.034	Not Calculated
444	BR	0.019	3.9×10^{-5}
473B	CS	0.019	Not Calculated
444	LS	0.018	3.8×10^{-5}
473A	CS	0.013	Not Calculated
504	LS	0.0075	1.5×10^{-5}

* Room: CS = crawlspace, BR = Bedroom, LS = Living Space
† Exposure Concentration in $\mu g/m^3$ (micrograms per cubic meter).
‡ Risk = IUR x C, where IUR is the derived Inhalation Unit Risk and C is the exposure concentration in $\mu g/m^3$.
§ An estimated excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. For example, an estimated cancer risk of 1×10^{-6} predicts the probability of one additional cancer over background in a population of 1 million. However, the true and actual risk is unknown and may be as low as zero.
Note: Cancer risk was not calculated for the crawlspace because exposure is not likely to be continuous.

DDT

DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane) and one of its break-down components, DDE, was detected in the air of Buildings 401, 407, 408, 409, 411, and 412. DDT does not get into the air easily because it has an extremely low vapor pressure of 1.60×10^{-7} at 20^{o} C, which is about 100 times lower than chlordane [ATSDR 2002].

Additionally, DDT is only slightly soluble (0.025 mg/kg) about twice as soluble as chlordane which is also relatively insoluble. Since the DDT application must have been more than 40 years ago when DDT was legal to use, two reasonable explanations for its presence in air are as follows: 1) wet; the ground was treated and it got wet or washed; and 2) dry; wood was treated and it decayed and the area was swept to make dust airborne.

> Wet: While DDT is very insoluble, it has a high activity coefficient in water –thus it can volatilize if activated by water. So if a surface has DDT on it or in its pore spaces and that surface is washed or wetted, the DDT can be activated and become airborne [ENEA 1996].
>
> Dry: Compounds with low volatility can become adsorbed onto particles and those particles can become airborne [ENEA 1996]. If a wood surface was treated with DDT and the wood broke down over time, sweeping, sanding, or scratching the wood could make it airborne.

ATSDR observed that custodial staff members were entering some rental cabins to clean during the air sampling. This can have a dramatic impact on the chemicals detected and their concentrations.

Wetting the surface of a material containing DDT can cause it to become airborne. ATSDR believes that this is the case for these buildings.

NPS-Specific Evaluation of DDT

DDT was detected in six of 45 buildings; all of them are rental cabins. Levels of DDT in air ranged from 0.0075 to 0.014 µg/m^3. All detected values represented a cancer risk range of 10^{-7} --much lower than the 10^{-6} acceptable level and therefore not a hazard.

However, if DDT was applied to a surface that could be contacted by children it may be a concern. Trace levels detected in the buildings may have been the result of cleaning indoor surfaces; this suggests impacted surfaces are in the living spaces and may be accessible to children. There is no evidence that this is occurring, but the presence of DDT in air is uncommon and the worst case scenario needs to be considered. Surface sampling of suspected DDT application sites indoors is recommended as soon as is practicable.

Children are at a greater risk than adults because they spend more time near the areas that were likely sprayed, such as floor boards. Children have continuous hand-to-mouth activity likely resulting in greater contact and ingestion of pesticide residues.

BHC - Lindane

Lindane is the common name for hexachlorocyclohexane (HCH), also known as benzene hexachloride (BHC). It is a man-made chemical that exists as eight chemical forms called isomers. The different isomers are named according to the position of the hydrogen atoms in the structure of the chemical. Gamma-BHC (or γ-BHC) is the isomer that is responsible for its insecticide properties. Technical-grade BHC, a mixture of several chemical forms of BHC, was also once used as an insecticide in the United States and typically contained about 10–15% of γ-BHC as well as the alpha (α), beta (β), delta (δ), and epsilon (ε) forms of BHC. It has been used on fruits, vegetables, forest crops, and animals. It can be purchased over-the-counter at the pharmacy to treat lice in humans. However, it has not been produced in the United States since 1976 [ATSDR 2005].

NPS-Specific Evaluation of BHC

Gamma BHC listed in the lab reports as gamma BHC was detected in five of 45 samples. The maximum detected value was 0.0180 µg/m^3 from the living space of Building 504. Delta BHC was detected in one of 45 samples at 0.01 µg/m^3. Due to insufficient scientific information from studies, ATSDR has not established a comparison value for BHC or its isomers. EPA's Office of Air Quality Planning and Standards has established a non-cancer screening value of 0.3 µg/m^3, 17-times greater than the maximum value detected in Building 504. Therefore, it is unlikely that any non-cancer health effects would occur from exposure to BHC in the buildings sampled.

EPA has derived an IUR of $(3.1 \times 10^{-4})^{-1}$ µg/m^3. Multiplying the IUR by the maximum exposure concentration (0.018 µg/m^3) indicates an estimated cancer risk of 5.5×10^{-6} for 30 years of exposure. Cancer risk estimates for 1-, 5-, and 30- years fall within EPA's target risk range of no to slight increased additional risk.

Limitations

In the absence of a definitive conclusion about the extent of the hazard presented by site conditions, this document focuses on reducing the current levels of pesticides in the indoor air of NPS buildings. This evaluation contains several limitations and uncertainties in characterizing the hazard risk because of the limited amount of toxicological information regarding the human health effects of the detected pesticides at levels similar to those found in NPS buildings. To address this uncertainty, ATSDR used a conservative (i.e., protective) approach that is consistent with the public health principle of prevention and believes the focus should be placed on ways to prevent, reduce, or eliminate exposure.

EPA's Inhalation Unit Risk values are derived from highly protective mathematical models applied to epidemiologic or experimental data for carcinogenic effects. The mathematical models extrapolate from higher experimental doses to lower environmental doses. Often, the experimental data represent exposures to chemicals at concentrations orders of magnitude higher than concentrations found in the environment. In addition, these models often assume that there are no thresholds for carcinogenic effects—a single molecule of a carcinogen is assumed to be able to cause cancer. The doses associated with these estimated hypothetical risks may be orders of magnitude lower than doses reported in the toxicology literature to cause carcinogenic effects. Using this approach provides an rough estimate of risk; the true or actual risk is unknown and could be as low as zero [EPA 2005].

Although ATSDR recognizes the utility of numerical risk estimates in risk analysis, the agency considers such estimates in the context of the variables and assumptions involved in their derivation and in the broader context of biomedical opinion, host factors, and actual exposure conditions. The actual parameters of environmental exposures must be given careful consideration in evaluating the assumptions and variables relating to both toxicity and exposure [ATSDR 1993b]. For that reason, risk characterization for NPS buildings is limited and cannot be used to predict health outcomes. Instead, ATSDR emphasizes the measures needed to prevent, reduce, or eliminate the risk. These measures have been demonstrated to reduce indoor air levels of contaminants.

It is unclear from the documents how many of the 58 buildings have been sampled over the years. Additionally, the testing of indoor air represents just one pathway that may be contributing to exposure of building occupants. Pesticide residues may be present in dust, on the surface of items, furniture, carpeting, kitchen cabinets, etc. It appears that the pesticide solutions were heavily applied to building materials at this site.

Children's Health Considerations

Pesticides were typically applied to areas low to the ground where children play and where dust collects. It is particularly unwise to allow children to occupy a home where they can come in direct contact with pesticide dusts. Children can put objects that have pesticide residues in their mouths, and generally put their hands in their mouths and touch their faces more often than adults. They also breathe a greater volume of air per body weight than adults. Thus, the behavior and physical characteristics of children can lead to higher exposures than adults. Therefore, ATSDR recommends that dust and/or wipe samples be collected.

Conclusions

1. ATSDR concludes that breathing the detected levels of pesticides (technical chlordane, aldrin, DDT, and lindane) present in the indoor air of ONSR NPS buildings is not expected to harm people's health.

2. The maximum detected air concentrations of technical chlordane and aldrin were found in the crawlspaces of Buildings 445B, 473B, and 445A. While continuous long-term exposure (24 hours per day for 70 years – an unlikely situation) to the pesticides found in crawlspaces of treated buildings might result in increased risk of cancer and non-cancerous health effects, more realistic short-term crawlspace visit scenarios are not expected to harm the health of adults.

3. Information provided to ATSDR indicates that chlordane may have been applied directly onto interior surfaces of some ONSR NPS buildings. In addition, some living space air samples were found to contain aldrin and DDT; this is unusual and may indicate that those pesticides were also applied directly onto interior surfaces. Wipe-samples of interior surfaces are needed to determine whether contaminated interior surfaces may represent a health concern to young children.

Recommendations

1. Although the levels of pesticides present in indoor air have not been shown to cause adverse health effects in adults, children, and unborn children, prudent public health practice dictates reducing pesticide exposure wherever possible, especially in living spaces. ATSDR recommends that NPS further reduce exposure in the treated buildings by using simple and effective measures like those NPS has successfully employed in Building 305. This is particularly important in building 523B, which had the highest indoor levels of chlordane and related compounds. This would add an additional margin of safety for occupants who use buildings on a long-term basis. Measures shown to be effective when properly installed and maintained include:

   - Installing a vapor barrier between the crawlspace and living space.
   - Insuring that the HVAC does not draw from the crawlspace.
   - Increasing ventilation of crawlspaces to the outside.
   - Sealing entry points from the crawlspaces where pipes or wires penetrate into the living space.
   - Adjusting thermostats to reduce large temperature swings by increasing the frequency that the system cycles (short cycles).
   - Reducing the release of pesticides from building materials in the building interior by sealing the exposed wood, concrete, and stone surfaces (including the fireplace mantle surface).
   - Limiting occupancy or consider alternative uses.

2. ATSDR recommends that indoor air in NPS buildings be resampled after indoor air pesticide reduction method(s) are completed to confirm that the concentrations in indoor air have decreased. Additional measures may be required if concentrations have not decreased.

3. ATSDR recommends that NPS take action to reduce exposure to crawlspace air in all buildings that were treated. Measures shown to be effective include:

   - Preventing children from accessing the crawlspaces.
   - Limiting occupancy or consider alternative uses.
   - Limiting the time adults spend in the crawlspace.
   - Changing clothes and washing hands immediately after accessing the crawlspace.
   - Washing contaminated clothes separately from other household laundry.
   - Placing stored items in vapor proof material, or not storing items in the crawlspace.

4. ATSDR recommends that NPS collect surface swipe samples for aldrin and DDT to determine if exposure to indoor surfaces presents a hazard to children. ATSDR is available to review and comment on recommended sampling results when they have been obtained.

Public Health Action Plan

Completed Actions:

1. NIOSH has conducted extensive sampling of indoor air at several ONSR buildings as well as human health evaluations since 1983.
2. A vapor barrier was installed in the crawlspace of Building 305.
3. ToxFree consultants provided additional sampling and conservative risk assessments for four buildings.

Planned Actions:

1. ATSDR will meet with NPS employees to discuss the findings of the health consultation and answer health questions.
2. ATSDR will assist in referring concerned individuals to the Association of Occupational and Environmental Clinics (AOEC), American College of Medical Toxicology (ACMT), and the Pediatric Environmental Health Specialty Unit (PEHSU).
3. ATSDR will share the health consultation with the National Institute of Occupational Safety and Health (NIOSH) for follow up regarding occupational exposures and concerns.

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Appendix A - Previous Investigations

Date(s)	Activities/ Results
October 1982	58 Bldgs treated with termiticide
February 1983	Bldg 305 retreated
1983	Residents complained of strong odors inside Bldg 305
July 1983	NIOSH detected chlordane in one male adult resident's blood (< 1 ng/mL). Another adult female and infant resident showed no detectable blood chlordane.
August 1983	NIOSH found no detectable levels of Chlordane in other two residents of Bldg 305
September 1983	NIOSH evaluated chlordane exposure in 6 bldgs. Three of the six buildings had chlordane levels above the National Research Council's (NRC) criterion of 5 micrograms/cubic meter (μg/m^3) for residences.
January 1984 to September 1984	NIOSH collected 680 samples in 36 buildings January 1-6 and September 9, 1984. Concentrations of chlordane in these samples ranged from 0.02 μg/m^3 to 210 μg/m^3, with levels in 19 of the samples exceeding the 5 μg/m3 NRC criterion for building interiors. These bldgs were closed.
September 1984	NIOSH conducted a medical evaluation of 18 NPS employees and their families and 10 Forest Service maintenance workers which included a health history questionnaire and blood analysis for chlordane and their metabolites. NIOSH found no uniform pattern of symptoms or reported medical conditions but concluded that individuals could be exposed to potentially harmful levels of chlordane. Residential air samples of NPS employees contained chlordane at levels 0.79 to 4.6 μg/m^3. Serum chlordane were found at levels from less than 1.0 ppb to 2.9 ppb. No residential home levels were obtained for the Forest Service workers. However, 5 of them participated in chlordane decontamination operations of Forest Service buildings. One had a serum chlordane level of 24 ppb (NIOSH 1987). No recommended limits for blood chlordane levels have been developed.
August 1987	NIOSH recommended ways to reduce exposure to chlordane. In summary: 1. Buildings 248A & B, 436, 444, 504, 523A & B should not be used until chlordane levels fall below the 5 μg/m^3 evaluation criterion. Natural ventilation by way of partially open windows and doors. Chlordane sampling should be done during the warmer summer months. Installation of a vapor barrier and positive ventilation in the crawlspaces. 2. Buildings 222, 305, 445, 446, 473A & B should have a vapor barrier of Saranex or Capran-C plastics be installed and have positive ventilation of the crawlspace. 3. Children should be prevented entry in to crawl spaces by barriers. 4. Personal protective equipment should be worn by those performing decontamination.
Date Unknown	Capran 77-C vapor barrier was installed in building 305 on the floor joists and sills in the main basement and crawlspace.

Previous Investigations (Continued)

Date(s)	Activities/ Results
June 1989	NIOSH sampled bldgs. in June 1989 and again in June 1990. Air chlordane concentrations ranged from 0.7 to 7.9 μg/m^3 in interior living spaces of buildings 305, 436, and 444. Chlordane-treated crawlspaces and basements had air concentrations up to 69 μg/m^3 in 1989. Building 318 had levels of chlordane in the living areas (0.5 μg/m^3) and the crawlspace (1.6 μg/m^3).
June 1990	NIOSH sampled bldgs. in June 1989 and again in June 1990. Air chlordane concentrations in the living spaces of these buildings ranged from 1.5 to 11 μg/m^3. Crawlspaces and basements had air concentrations up to 70 μg/m^3. One year later, there were no significant changes in the chlordane concentrations in the crawlspaces and basements. For bldg. 305, NIOSH recommended that 1) the crawlspace and basement of bldg. 305 be locked to keep children from playing there 2) no food, clothing, furniture, or toys be stored there 3) positive ventilation would be beneficial to keep chlordane levels from being emitted into the main basement and upstairs living space and 4) the application of a concrete sealant to the wall that separates the small basement area from the main basement area would also help reduce emissions. Bldgs. 436 and 444 had levels of chlordane above 5 μg/m^3. NIOSH recommended that these bldgs. not be occupied, but if they were to be occupied, then the crawlspaces/cellar/basements should be locked to keep children from playing there and no food, clothing, furniture, or toys should be stored there.
October 1995	NIOSH collected 6 air samples in Bldg 523A. Air chlordane concentrations in the living areas ranged from 0.8 to 1.7 μg/m^3. Concentrations of chlordane in the crawlspace air was 10 μg/m3. Levels in the living space decreased 10 fold over a 9 year period (1984 results). Levels in the crawlspace decreased from 27 ug/m3 to 10 μg/m3 over that same period. NIOSH recommended that children not be allowed to play in the crawlspace.
August 1996	NIOSH collected 34 samples from 14 buildings sampling and analysis according to NIOSH Method 5510 (NIOSH 1997). Interior living spaces of all buildings sampled were less than the 5 μg/m^3 NRC interim value (max 1.9 μg/m^3). Crawlspaces had levels of chlordane up to 41 μg/m^3. NIOSH recommended that children be prevented from accessing crawlspaces.
August 1997	NIOSH letter to NPS summarizing investigations to date.
November 2012	NPS contracted with ToxFree, Inc. to reevaluate pesticide levels in several buildings. They concluded that some buildings were still above health-based advisory levels.
June 2013	NPS contacted ATSDR to re-evaluate the investigations. ATSDR contacted EPA to assist with sample collection. EPA contractors collected samples in August and September 2013. Sampling results for 45 locations within 24 buildings show that 8 buildings have elevated levels of pesticides.

Appendix B – Building Details

Bldg	Description	Construction	Use
248A,B	Round Spring Employee Housing Duplex	Frame w/ concrete foundation	Each housing unit: 3 BR, 1 story w/crawl space. Unoccupied.
305	Powder Mill Employee Housing	Frame w/ concrete foundation	Housing: Split level housing with 1/2 basement. 3 BR 1. 5 BA. Unoccupied.
401H	Big Spring Rental Cabin, Stone walls, floor, and fireplace	Stone foundation and walls	Rental Cabin, Visitor rental.
404H	Big Spring Rental Cabin, Wood walls & floor, stone fireplace	Frame w/ concrete foundation, Wood siding	Rental Cabin. Visitor rental.
405H	Big Spring Rental Cabin, Wood walls & floor, stone fireplace	Frame w/ concrete foundation, Wood siding	Rental Cabin. Visitor rental w/crawl space
406H	Big Spring Rental Cabin, Wood walls & floor	Concrete Slab on Grade, Wood siding	Rental Cabin. Visitor rental w/crawl space
407H	Big Spring Rental Cabin, Wood walls & floor	Slab Floor, Wood siding	Rental Cabin. Visitor rental w/crawl space
408H	Big Spring Rental Cabin, Wood walls & floor, stone fireplace	Stone foundation, Wood siding	Rental Cabin. Visitor rental w/crawl space
409H	Big Spring Rental Cabin, Wood walls & floor	Concrete Slab on Grade, Wood siding	Rental Cabin. Visitor rental w/crawl space
410H	Big Spring Rental Cabin, Wood walls & floor, stone fireplace	Concrete Slab on Grade, Wood siding	Rental Cabin. Visitor rental w/crawl space
411H	Big Spring Rental Cabin Wood walls & floor	Wood Frame w/ concrete foundation, wood siding	Rental Cabin. Visitor rental w/crawl space
412H	Big Spring Rental Cabin, Wood walls & floor, stone fireplace	Wood Frame w/ concrete foundation, wood siding	Rental Cabin. Visitor rental w/crawl space
413H	Big Spring Rental Cabin, Wood walls & floor	Wood Frame w/ concrete foundation, wood siding	Rental Cabin. Visitor rental w/crawl space
414H	Big Spring Rental Cabin, Wood walls, floor, stone fireplace	Stone foundation and walls	Rental Cabin Visitor rental w/crawl space
415H	Big Spring Employee Housing, Drywall & wood floor, stone fireplace	Wood Frame w/ concrete foundation, wood siding	Residence for concession management. Children currently reside here. Two story 3BR 2BA with 2BRs upstairs and one down w/crawl space
416	Big Spring Wood walls & floor, stone fireplace	Stone foundation & basement, Wood siding	Office for NPS personnel
444	MAY HOUSE QTRS, Drywall, wood floors	Wood Frame, siding w/ concrete foundation, crawlspace	Unoccupied Housing
445A,B	Big Spring PARTNEY QTRS, Wood panel walls, carpet floors	Concrete foundations, wood siding, crawlspace	Occupied Housing. No children currently reside here. Two story modified farmhouse with 2 apartments. Currently occupied by firefighters. 2 BRs, 1BA, Kit, and LS.
473A	Big Spring Employee housing/Duplex, Wood panel walls, wood floor	Concrete Slab on Grade, Wood siding, crawlspace	Occupied Housing. No children currently reside here. Single story 3 BR 1.5 BA duplex connected by two single car garages.
473B	Big Spring Employee housing/Duplex, Drywall, wood floor	Concrete Slab on Grade, Wood siding, crawlspace	Occupied Housing. No children currently reside here. Single story 3 BR 1.5 BA duplex connected by two single car garages.
499	Big Spring Old fire cache bldg	Concrete Slab on Grade, Wood siding	Old fire cache building with workout/weight area
504	Alley Spring Employee housing	ROCK FOUNDATION/FRAME, full basement	Unoccupied employee housing.
505	ALLEY CABIN	Frame w/ concrete foundation	Housing. Seasonal housing. Currently unoccupied.
506	Alley Spring Cabin, Drywall	Stone foundation, Wood siding	Housing. Seasonal housing. Currently unoccupied.
523A	Alley Spring Office, exercise room /DUPLEX, Drywall, wood floors	Frame w/ concrete foundation	Occupational Occupancy. Single story 3BR 1.5BA duplex modified into Park Ranger offices; 3 offices with living space used as meeting space.
523B	Alley Spring Employee Housing QTRS/DUPLEX, Drywall, wood floors	Frame w/ concrete foundation	Unoccupied Housing. Single story 3 BR 1.5 BA duplex connected by two single car garages.

Appendix C: Sampling and Analysis Methods for 2013 Air Samples

Each sample was collected in accordance with EPA Method TO-10A, using an air sampling pump calibrated to a flow rate of approximately 5 liters per minute. A small glass sampling tube containing a polyurethane foam (PUF) plug was connected to each sampling pump via dedicated tubing. At indoor living/working/exercise areas, the "mini-PUF" sampling tube was affixed to a portable stand or other apparatus to allow collection of air from a breathing zone height of approximately 5 feet above the floor. EPA Method TO-10A is used for the analysis of 26 pesticides and polychlorinated biphenyls in ambient air. The procedure uses Gas Chromatographic/Multi-Detector Detection (GC/MD).

Sampling for chlordane and analyzing for chlordane

It is common to read the expressions “samples were collected for…” or “samples were analyzed for…” a particular substance. While these expressions mean that the sampling or analytical methodology is inclusive of and is appropriate for use for that substance, it is often be misinterpreted to mean that the method is exclusive – and that only that substance and no other could be obtained from the sample matrix or method used.

In the laboratory, technical grade chlordane, which has been carefully analyzed for α- and γ-chlordane content using a primary standard of pure isomers, is used to prepare analytical standards. Technical grade chlordane is preferred over α- and γ-chlordane for analytical standards because it is more readily available and it provides a chromatographic fingerprint pattern. Because most samples of technical grade chlordane have sufficiently matchable fingerprints, a sample of the bulk material is not required with each set of samples for use as the analytical standard. A bottle of technical grade chlordane can be calibrated with the primary standard and used to make standards for most samples [OSHA not dated].

According to the NIOSH Manual of Analytical Methods, the analytical procedures developed by NIOSH (Method 5278 and 5510) require that the sample be desorbed with toluene and analyzed by Gas Chromatograph with an electron capture detector (ECD). NIOSH Method 5510 states that chlordane, accompanied by a mixture of penta-, hexa-, hepta-, and nonachlorinated compounds, is defined by a group of five chromatographic peaks. It is necessary to determine the percentage of chlordane and its isomers in the standards used. “The NIOSH approach was to base the analysis on α- and γ-chlordane plus several related isomers that are typically present in technical grade chlordane” [NIOSH 1980, NIOSH 1994a, OSHA not dated].

EPA Method 8080A and also EPA Method TO-10A cover 26 pesticides and Aroclor (PCB) mixtures and are suitable for monitoring-type analyses. Analytes are detected by an electron capture detector (ECD) or an electrolytic conductivity detector in the halogen mode (HECD).

All the above methods have been used during the course of the sampling and evaluation of pesticides in ONSR buildings since 1983. They all are able to detect and quantify technical chlordane.

Appendix D - Methodology

Health Guidelines Exposure Limits, and Comparison Values

ATSDR and other agencies and groups compare site concentrations with health guidelines, exposure limits, or other comparison values, when appropriate, to evaluate exposures to substances detected in various environmental media and from various routes of exposure (typically from oral or inhalation). ATSDR has developed health guidelines and environmental guidelines to use when conducting the screening analysis and evaluating exposures to substances found at sites under investigation.

As an initial screen, ATSDR uses environmental screening values such as EMEGs and CREGs to compare directly with concentrations detected in the environment. ATSDR's EMEG is a concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a comparison value used to select contaminants of potential health concern and is based on ATSDR's minimal risk level (MRL). ATSDR's CREG is the concentration of a chemical in air, soil or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a comparison value used to select contaminants of potential health concern and is based on the cancer slope factor (CSF).

Health guidelines are substance-specific doses or concentrations derived using toxicological information. Where adequate dose-response data exist, health guidelines are derived for both the ingestion or inhalation routes of exposure. Health guidelines include ATSDR's minimal risk levels (MRLs). No health guidelines have been developed by ATSDR for dermal exposures. Environmental guidelines are media-specific substance concentrations derived from health guidelines using default exposure assumptions.

In addition to comparison values derived by ATSDR, other federal, and some state agencies have developed similar types of health-based guidelines for concentrations of substances in water, soil, air, and food that maybe used, when appropriate, to evaluate exposures to substances detected in various site media. Non-ATSDR comparison values include: EPA's Reference Doses, Reference Concentrations, Cancer Slope Factors, Inhalation Unit Risks, FDA's action levels; OSHA's Permissible Exposure Limits, and NIOSH's Recommended Exposure Limits to name a few.

Comparison values are derived when reliable and sufficient data exist to identify the target organ(s) of effect or the most sensitive health effects(s) for a specific duration for a given route of exposure. MRLs and RfCs are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. MRLs and RfCs are based only on non-cancerous effects and are derived for substances by factoring the most relevant documented no-observed-adverse-effects level (NOAEL) or lowest-observed-adverse-effects level (LOAEL) and an uncertainty factor. MRLs and RfCs are screening values only and are not indicators of health effects. Exposures to substances at doses above MRLs and RfCs will not necessarily cause adverse health effects and need to be further evaluated.

ATSDR uses a conservative (i.e., protective) approach to address this uncertainty. This is consistent with the public health principle of prevention. Although human data are preferred, comparison values often must be based on animal studies because relevant human studies are lacking. In the absence of

evidence to the contrary, ATSDR assumes that humans are more sensitive to the effects of hazardous substances than animals and that certain persons may be particularly sensitive.

Most comparison values contain a degree of uncertainty because of the lack of precise toxicological information about the people who might be most sensitive (e.g., children, elderly, or those with pre-existing illnesses) to the effects of environmental contamination. This uncertainty is captured by multiplying a studied value by factors of 10 or 100 to account for various uncertainties. In this way comparisons are designed to be highly protective of public health.

Uncertainties are accounted for by applying "uncertainty" factors to the NOAEL. For example, an uncertainty factor of between 1 and 10 may be applied for extrapolation from animal doses to human doses and/or a factor between 1 and 10 may be applied to account for sensitive individuals. When more than one uncertainty factor is applied, the uncertainty factors are multiplied. In this example, the uncertainty factor would be 100—10 for the extrapolation to humans and 10 to account for sensitive individuals.

Values Used

For the purposes of this evaluation, the discussion of technical chlordane versus pure chlordane is presented in the body of the document. Because the health guidelines used by NIOSH, OSHA, EPA, and ATSDR are based on technical-grade chlordane and not pure chlordane or its isomers, ATSDR combined (additive) the analytical results of alpha-chlordane, gamma chlordane, and heptachlor which are used the combined value as comparison with EPA’s RfC and EPA’s Inhalation Unit Risk (IUR) value for technical chlordane. Even though EPA has derived an inhalation unit risk to aid in cancer evaluations for most of the pesticides detected in the NPS buildings, only technical chlordane has comparison values for non-cancerous health effects.

For aldrin, heptachlor epoxide, DDT, DDE, and BHC (combined isomers), ATSDR used EPA’s IUR value for each substance. The available inhalation data from the scientific literature are considered inadequate for the development of ATSDR MRLs for these substances. ATSDR evaluated heptachlor individually and also as an additive to the chlordane mixture.

The excess cancer risk for a receptor exposed via the inhalation pathway can be estimated with the following equation:

Risk = IUR x EC,

where: IUR ($\mu g/m^3)^{-1}$ = Inhalation Unit Risk; and EC ($\mu g/m^3$) = exposure concentration

Table D1. Living Space Air Cancer Risk Estimate Using EPA's Inhalation Unit Risk

Chemical Substance	Concentration Range ($\mu g/m^3$)*		EPA's Inhalation Unit Risk for 30 yr	Cancer Risk Estimate†
	Minimum	Maximum		
Technical Chlordane (combined)	0.0086	.07	0.0001	3.3×10^{-5}
Heptachlor Epoxide	0.0071	0.064	0.0026	7.1×10^{-5}
Aldrin	0.0075	0.019	0.0049	3.9×10^{-5}
4,4'-DDT	0.0075	0.014	0.000097	5.4×10^{-7}
BHC (combined)	0.0075	0.0180	0.00031	5.5×10^{-6}
4,4'-DDE	0.0089	0.0089	0.000097	1.8×10^{-6}

* Exposure Concentration in $\mu g/m^3$ (micrograms per cubic meter).
† EPA's Inhalation Unit Risk is a value used to calculate cancer risk using the formula Risk = IUR x EC
Where: Inhalation Unit Risk = IUR ($\mu g/m^3)^{-1}$ or (1/ micrograms per cubic meter) and exposure concentration = EC ($\mu g/m^3$) micrograms per cubic meter. Risk is expressed as an extrapolated value of a the upper bound (maximum) theoretical chance 1 additional cancer case out of 1,000,000 exposed individuals in their lifetime. The true and actual risk is unknown and may be as low as zero.

Because the inhalation unit risk is based on continuous exposure for a lifetime (70 years), this product may be scaled by the fraction of time a person is assumed to be exposed to the contaminant. We multiplied the IUR by 30/70 for a 30 year exposure.

Below are Occupational Comparison Values used to determine workplace exposures. These values are typically higher than comparison values ATSDR or EPA use for evaluating non-occupational exposures. One reason for this is the assumption that a worker population is considered "healthy", whereas, the general population has more sensitive subpopulations such as children and pregnant women that make them more susceptible to adverse health effects.

The occupational comparison values below were not used as comparison values in this evaluation, nor were they the basis of the earlier NIOSH investigations. They are presented here to NPS for informational purposes only.

Table D2. Occupational Comparison Values

	NIOSH REL[a] (µg/m³)[b]	OSHA PEL[c] (µg/m³)	ACGIH TLV[d] (µg/m³)
Technical Chlordane (combined)	500	500	500
Aldrin	250	250	50
4,4'-DDT	500	1000	1000
Endrin	100	100	100
BHC Lindane (combined)	500	500	500

(a) NIOSH REL = National Institute of Occupational Safety and Health Recommended Exposure Limit - for exposure of an employee (occupational) to a chemical substance or physical agent for up to 10-hour time weighted averages during a 40-hour work week, not legally enforceable
(b) µg/m3 – microgram per cubic meter
(c) OSHA PEL = Occupational Safety and Health Administration Permissible Exposure Limit – for occupational exposure for time-weighted averages for 8-hour work day, a legal limit
(d) ACGIH TLV = American Conference of Governmental Industrial Hygienists Threshold Limit Values for occupational exposure 8-hour time weighted averages.

Appendix E – Data Summary

BLDG NUMBER	Room	Aldrin	Heptachlor	Heptachlor Epoxide	α-Chlordane	γ-Chlordane	γ-BHC	d-BHC	DDE	DDT	Endrin
		μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³
248A	LS	ND	0.19	0.015	0.03	0.084	ND	ND	ND	ND	ND
248A	BR	ND	0.19	0.016	0.031	0.088	ND	ND	ND	ND	ND
248B	LS	ND	0.2	0.014	0.028	0.08	ND	ND	ND	ND	ND
248B	BR	ND	0.2	0.015	0.031	0.092	ND	ND	ND	ND	ND
305	LS	ND	0.031	0.017	0.044	0.094	ND	ND	ND	ND	ND
305	BR	ND	0.018	ND	0.009	0.021	ND	ND	ND	ND	ND
305	CS	ND	0.016	0.034	0.096	0.21	ND	ND	ND	ND	ND
401 H	LS	ND	ND	ND	ND	0.0086	ND	0.01	0.0089	0.013	0.0093
404H	LS	ND	0.007	0.011	0.015	0.033	ND	ND	ND	ND	ND
405H	LS	ND	ND	0.017	0.034	0.077	ND	ND	ND	ND	ND
406H	LS	ND	ND	0.01	0.021	0.05	ND	ND	ND	ND	ND
407H	LS	ND	0.012	0.019	0.052	0.11	ND	ND	ND	0.0084	ND
408H	LS	ND	0.0075	0.0097	0.021	0.05	ND	ND	ND	0.0075	ND
409H	LS	ND	0.0088	0.014	0.032	0.066	ND	ND	ND	0.0094	ND
410H	LS	ND	0.017	0.0071	0.012	0.032	ND	ND	ND	ND	ND
411 H	LS	ND	ND	0.009	0.014	0.033	ND	ND	ND	0.0093	ND
412H	LS	ND	0.033	0.047	0.14	0.27	ND	ND	ND	0.0083	0.02
413H	LS	ND	ND	0.0087	ND	0.015	ND	ND	ND	ND	ND
414H	LS	ND	0.012	0.01	0.018	0.043	ND	ND	ND	ND	ND
415H	LS	ND	ND	ND	0.013	0.018	ND	ND	ND	ND	ND
415	BR	ND	0.0076	ND	0.0094	0.014	ND	ND	ND	ND	ND
416	O	ND	0.0093	0.0091	0.023	0.055	ND	ND	ND	ND	ND
444	LS	0.018	0.055	0.063	0.19	0.42	ND	ND	ND	ND	ND
444	BR	0.019	0.047	0.064	0.18	0.41	ND	ND	ND	ND	ND
445A	LS	ND	0.032	0.028	0.08	0.16	ND	ND	ND	ND	ND
445A	BR	ND	0.022	0.014	0.043	0.084	ND	ND	ND	ND	ND
445B	LS	ND	0.019	0.0089	0.03	0.065	ND	ND	ND	ND	ND
445B	BR	ND	0.016	0.0075	0.023	0.061	ND	ND	ND	ND	ND
445B	CS	0.034	0.067	0.2	0.77	1.3	ND	ND	ND	ND	ND
473A	LS	ND	0.056	ND	0.013	0.022	ND	ND	ND	ND	ND
473A	BR	ND	0.058	ND	0.014	0.025	ND	ND	ND	ND	ND
473A	CS	0.013	0.39	0.14	0.28	0.65	ND	ND	ND	ND	ND
473B	LS	ND	0.049	ND	0.015	0.042	ND	ND	ND	ND	ND
473B	BR	ND	0.05	ND	0.015	0.038	ND	ND	ND	ND	ND
473B	CS	0.019	0.36	0.11	0.35	0.87	ND	ND	ND	ND	ND
499	WM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
504	LS	0.0075	0.061	0.017	0.055	0.13	0.018	ND	ND	ND	ND
504	BR	ND	0.061	0.017	0.05	0.12	0.017	ND	ND	ND	ND
505	LS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
506	LS	ND	ND	ND	0.017	0.046	0.012	ND	ND	0.014	ND
523A	WM	ND	0.077	0.0096	0.026	0.079	ND	ND	ND	ND	ND
523A	O	ND	0.12	0.02	0.044	0.12	ND	ND	ND	ND	ND
523A	MS	ND	0.12	0.022	0.051	0.14	ND	ND	ND	ND	ND
523B	LS	ND	0.61	0.02	0.042	0.12	0.0076	ND	ND	ND	ND
523B	BR	ND	0.56	0.017	0.036	0.11	0.0075	ND	ND	ND	ND

* Room: CS=crawlspace, BR=Bedroom, LS=Living Space, MS=Meeting Space, O=Office, WM=Weight Room.

† Exposure Concentration in μg/m3 (micrograms per cubic meter).

ND Not Detected. From: Tetra Tech, Inc. 2013e. Data Summary Report, NPS Chlordane Sampling Project, September 27.